electrophoresis through a 10% polyacrylamide gel (19:1 cross link), with 7M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA.

The results were visualized by autoradiography and are shown in Figure 22B with the enzymes indicated as follows: I is native *Taq* DNAP; II is native *Tfl* DNAP; III is Cleavase® BX shown in Figure 4E; IV is Cleavase® BB shown in Figure 4F; V is the mutant shown in Figure 5B; and VI is Cleavase® BN shown in Figure 4G.

Structure 2 was used to "normalize" the comparison. For example, it was found that it took 50 ng of *Taq* DNAP and 300 ng of Cleavase® BN to give similar amounts of cleavage of Structure 2 in thirty (30) minutes. Under these conditions native *Taq* DNAP is unable to cleave Structure 3 to any significant degree. Native *Tfl* DNAP cleaves Structure 3 in a manner that creates multiple products.

By contrast, all of the mutants tested cleave the linear duplex of Structure 3. This finding indicates that this characteristic of the mutant DNA polymerases is consistent of thermostable polymerases across thermophilic species.

The finding described herein that the mutant DNA polymerases of the present invention are capable of cleaving linear duplex structures allows for application to a more straightforward assay design (Figure 1A). Figure 23 provides a more detailed schematic corresponding to the assay design of Figure 1A.

The two 43-mers depicted in Figure 23 were synthesized by standard methods. Each included a fluorescein on the 5'end for detection purposes and a biotin on the 3' end to allow attachment to streptavidin coated paramagnetic particles (the biotin-avidin attachment is indicated by "   ").

Before the trityl groups were removed, the oligos were purified by HPLC to remove truncated by-products of the synthesis reaction. Aliquots of each 43-mer were bound to M-280 Dynabeads (Dynal) at a density of 100 pmoles per mg of beads. Two (2) mgs of beads (200 μl) were washed twice in 1X wash/bind buffer (1 M NaCl, 5 mM Tris-Cl, pH 7.5, 0.5 mM EDTA) with 0.1% BSA, 200 μl per wash. The beads were magnetically sedimented between washes to allow supernatant removal. After the second wash, the beads were resuspended in 200 μl of 2X wash/bind buffer (2 M Na Cl, 10 mM Tris-Cl, pH 7.5 with 1 mM EDTA), and divided into two 100 μl aliquots.

Each aliquot received 1 µl of a 100 µM solution of one of the two oligonucleotides. After mixing, the beads were incubated at room temperature for 60 minutes with occasional gentle mixing. The beads were then sedimented and analysis of the supernatants showed only trace amounts of unbound oligonucleotide, indicating successful binding. Each aliquot of beads was washed three times, 100 µl per wash, with 1X wash/bind buffer, then twice in a buffer of 10 mM Tris-Cl, pH 8.3 and 75 mM KCl. The beads were resuspended in a final volume of 100 µl of the Tris/KCl, for a concentration of 1 pmole of oligo bound to 10 µg of beads per µl of suspension. The beads were stored at 4°C between uses.

The types of beads correspond to Figure 1A. That is to say, type 2 beads contain the oligo (SEQ ID NO:33) comprising the complementary sequence (SEQ ID NO:34) for the alpha signal oligo (SEQ ID NO:35) as well as the beta signal oligo (SEQ ID NO:36) which when liberated is a 24-mer. This oligo has no "As" and is "T" rich. Type 3 beads contain the oligo (SEQ ID NO:37) comprising the complementary sequence (SEQ ID NO:38) for the beta signal oligo (SEQ ID NO:39) as well as the alpha signal oligo (SEQ ID NO:35) which when liberated is a 20-mer. This oligo has no "Ts" and is "A" rich.

Cleavage reactions comprised 1 µl of the indicated beads, 10 pmoles of unlabelled alpha signal oligo as "pilot" (if indicated) and 500 ng of Cleavase® BN in 20 µl of 75 mM KCl, 10 mM Tris-Cl, pH 8.3, 1.5 mM $MgCl_2$ and 10 µM CTAB. All components except the enzyme were assembled, overlaid with light mineral oil and warmed to 53°C. The reactions were initiated by the addition of prewarmed enzyme and incubated at that temperature for 30 minutes. Reactions were stopped at temperature by the addition of 16 µl of 95% formamide with 20 mM EDTA and 0.05% each of bromophenol blue and xylene cyanol. This addition stops the enzyme activity and, upon heating, disrupts the biotin-avidin link, releasing the majority (greater than 95%) of the oligos from the beads. Samples were heated to 75°C for 2 minutes immediately before electrophoresis through a 10% polyacrylamide gel (19:1 cross link), with 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. Results were visualized by contact transfer of the resolved DNA to positively charged

nylon membrane and probing of the blocked membrane with an anti-fluorescein antibody conjugated to alkaline phosphatase. After washing, the signal was developed by incubating the membrane in Western Blue (Promega) which deposits a purple precipitate where the antibody is bound.

Figure 24 shows the propagation of cleavage of the linear duplex nucleic acid structures of Figure 23 by the DNAP mutants of the present invention. The two center lanes contain both types of beads. As noted above, the beta signal oligo (SEQ ID NO:36) when liberated is a 24-mer and the alpha signal oligo (SEQ ID NO:35) when liberated is a 20-mer. The formation of the two lower bands corresponding to the 24-mer and 20-mer is clearly dependent on "pilot".

EXAMPLE 6

5' Exonucleolytic Cleavage ("Nibbling") By Thermostable DNAPs

It has been found that thermostable DNAPs, including those of the present invention, have a true 5' exonuclease capable of nibbling the 5' end of a linear duplex nucleic acid structures. In this example, the 206 base pair DNA duplex substrate is again employed (see above). In this case, it was produced by the use of one ^{32}P-labeled primer and one unlabeled primer in a polymerase chain reaction. The cleavage reactions comprised 0.01 pmoles of heat-denatured, end-labeled substrate DNA (with the unlabeled strand also present), 5 pmoles of pilot oligonucleotide (see pilot oligos in Figure 12A) and 0.5 units of DNAPTaq or 0.5 μ of Cleavase® BB in the *E. coli* extract (see above), in a total volume of 10 μl of 10 mM Tris•Cl, pH 8.5, 50 mM KCl, 1.5 mM $MgCl_2$.

Reactions were initiated at 65°C by the addition of pre-warmed enzyme, then shifted to the final incubation temperature for 30 minutes. The results are shown in Figure 25A. Samples in lanes 1-4 are the results with native *Taq* DNAP, while lanes 5-8 shown the results with Cleavase® BB. The reactions for lanes 1, 2, 5, and 6 were performed at 65°C and reactions for lanes 3, 4, 7, and 8 were performed at 50°C and all were stopped at temperature by the addition of 8 μl of 95% formamide with 20